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COST EFFECTIVENESS STUDY FOR A SYSTEM FACILITY

June 1966

Prepared for
U.S. NAVY ELECTRONICS LABORATORY
San Diego, California
Under Contract N123(953)54149A

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1. INTRODUCTION

This report describes a comparative study by ARINC Research Corporation of six alternative facilities for system-level evaluation at the Navy Electronics Laboratory. This study differs ~~in~~ two ways from past analyses of alternative facilities. First, the intended uses of the facility are redefined to include the evaluation of shipboard electronic systems other than the communications system for which the facility was originally planned. Second, the functional capabilities of each alternative facility are compared from a cost-effectiveness standpoint. Although these

Admittedly, the above-mentioned relationships necessitates a certain degree of subjectiveness. For this reason, an attempt is made to provide ~~or display~~ the information in such a way as to allow the reader to introduce his own subjective estimates and reformulate the results. Any effectiveness model will, in a like manner, have some subjective characteristics which are introduced to bridge gaps in information. In this study, Bayesian weighting factors were used as a means of introducing experience factors where the accumulation of factual data was impractical. However, in the application of these weighting factors, the effect of each on the modified cost of ownership of the systems to be evaluated was taken into consideration. Thus the effectiveness of the alternative facilities is related to the impact of system evaluation on the cost of ownership and delay in delivery of each system.

The intent of this study is to present sufficient data to point up the differences between the alternative facilities. Based on the significant differences, the most desirable alternative can be selected.

2. SUMMARY

2.1 Requirements

Certain requirements were chosen as criteria for the evaluation of the six alternative facilities. These requirements are discussed in sections 2.1.1 through 2.1.3.

2.1.1 Technical Requirements

Table 2-1 summarizes the technical requirements for the test facility. Each requirement is expressed two ways: as minimum acceptable and as desirable but not mandatory. A facility must possess at least the minimum characteristics to be acceptable as an alternative. Each acceptable alternative is then graded as to its effectiveness in providing the desirable characteristics. The method of grading is described in section 4; the rationale supporting the method is discussed in section 3.

2.1.2 Space Requirements

The minimum floor space required for the facility was estimated as follows:

SACOM NSACS/NFF	10,000 ft^2
Additional and supporting systems	20,000
Administrative (security office, guard, etc.)	1,000
Personnel comfort (rest areas, restrooms)	1,000
Air conditioning, switchboard, power station, etc.	500
+10 percent for passageways, entrances, etc.	3,250
Total:	35,750 ft^2

To allow for growth, a capacity for expansion to twice this size is considered desirable.

2.1.3 Alternative Facilities

The alternative facilities are described in section 2.2. Note that although Battery Ashburn is categorized as an existing building, a new building of 26,500 square feet will be required to meet the minimum space requirements.

TABLE 2-1

SUMMARY OF TEST FACILITY REQUIREMENTS

Requirement	Minimum Acceptable Characteristics	Desirable Characteristics
Floor Space	35,750 ft^2	Expandable to 71,500 ft^2
Accessibility		
Location convenience	Reachable by private transportation	Reachable by both public and private transportation
Proximity to NEL	Not greater than 30 minutes traveling time (by automobile) from NEL	Less than 15 minutes traveling time (by automobile) from NEL
Parking	Space for 100 cars	Expandable to accommodate 300 cars
Entryway	Work spaces can receive 6'×4'×4' objects without modification	Work spaces can receive 6'×8'×8' objects without modification
Elevators	2-ton capacity, 40 ft^2 area; running to all floors and roof	4-ton capacity, 60 ft^2 area; running to all floors and roof
Helipad	Helicopter can land by prearrangement	Helicopter can land without prearrangement
Microwave line to NEL	Possible with one repeater on existing Government site	Direct line of sight to NEL
Security		
Secret	Secret area does not require additional guard	Secret area does not require additional guard
Top Secret (T/S)	Top secret area feasible with one additional guard	Top secret area feasible without extra guard
Antenna Facility		
Scope	Room for approximately one full-scale NFF suit	100 percent additional area for evaluation and experimentation
Counterpoise	Copper mesh	Simulated ship's deck
View	No external obstruction above 10° elevation	No external obstruction above 5° elevation
Proximity	No objects above roofline within 50 feet	No objects above roofline within 500 feet
RF Noise Environment		
Noise Level	(Per specification)	(Per specification)
Restriction	Can radiate 10 kw below 30 Mc, 1 kw above 30 Mc	No limit
Packaging Flexibility	Sufficient to allow relocation of screened areas	Can be readily repartitioned to accommodate full-scale mock-up
Aesthetic Qualities	Not less than minimum existing in same location	Better than adjacent facilities

2.2 Facility Alternatives

2.2.1 Possibilities

In selecting the test-facility alternatives, an attempt was made to narrow the field as much as possible. An extreme case of only two alternatives ("in the Bunker Hill", "in a building") was examined and found to be the simplest to analyze but the least informative. The other extreme was to weigh all possible choices, including all those previously considered (see Table 2-2). Although this approach would be the most informative, time limitations and the complexity of data gathering and analysis indicated that a moderate number of most likely choices should be considered. Even then, each choice had to be carefully defined to prevent escalation into a large family of subalternatives.

The approach used throughout this study has been to ensure flexibility sufficient to allow other alternatives to be considered in the decision matrix.

2.2.2 Alternatives Selected

Three major alternatives, each divided into two subalternatives, were designated as follows:

(1) Bunker Hill

A. At Pier F, NAS, North Island

B. Adjacent to the east shore of Pt. Loma

(2) New Building

A. West side of Pt. Loma, water-level building

B. Building within the present NEL compound

(3) Existing Building

A. Battery Ashburn (with additional construction)

B. Leased building

2.2.3 Description of Alternatives

1A — The Bunker Hill is an aircraft carrier removed from the reserve fleet and made available to the NEL as a possible system facility. It has been partially prepared for such use, and electromagnetic research studies are presently being conducted on board. In its present location (Pier F, North Island) it will be considered as an alternative.

TABLE 2-2

ALTERNATIVE FACILITIES CONSIDERED TO DATE

Facility Afloat	Facility Ashore	Geographical Location
	New Building	Pt. Loma NEL Compound* Waterfront, west side*
		Naval repair facility
		Border field station
	Existing Building	
	Battery Ashburn	Atop Pt. Loma, 2 miles west of NEL compound*
	Leased Building	Within 15-mile radius of NEL compound*
Barge		Moored west of Pt. Loma
Bunker Hill		Breakwater west of Pt. Loma With causeway Without causeway
		Pier F, North Island*
		East side of Pt. Loma, south of Ballast Point*
		Moored west of Pt. Loma, without breakwater
Operating Ship (NEL control)		Pier, Pt. Loma
		Without pier, San Diego harbor
Operating Ship (Line)		On request
Tower† (2)		West side of Pt. Loma

*Considered in ARINC Research study.
†Same as afloat from electromagnetic standpoint.

1B — There is a possibility that the Bunker Hill can be moved to the sheltered east shore of Pt. Loma. A preliminary examination of the available space indicates that the partially sheltered coastline, south of Ballast Point and close to the cliffs, is the only space still available for mooring a ship as large as the Bunker Hill.

2A — A water-level building on the west shore of Pt. Loma has been considered in previous studies. This location would partially simulate the electromagnetic and RF radiation characteristics of an actual ship. A lead-coated roof and a tower are included in the specifications to simulate a suitable ground plane. Rough estimates were used in arriving at the cost of this building.

2B — A new building located atop Pt. Loma, within the NEL compound, has been specified and requested as MILCON No. P027. Although this building was not specifically intended as an NEL system test facility, all or part of it could be so designated with little change in plans.

3A — Battery Ashburn is an underground complex located on Pt. Loma within easy commuting distance (5 minutes) of the central compound. Although most of the space has been committed to other projects, the Battery could be made available, either in part or in total, for the facility. Considering that 9,000 square feet of existing space is available, a new building of 26,750 square feet would be required atop Battery Ashburn.

3B — Many buildings are available in San Diego on a lease basis. This possibility should be considered in that it represents a considerable variance from previous considerations. A cost effectiveness study may reveal that a leased facility is the most economical and effective.

2.3 Summary and Conclusions

The results of this study indicate quite clearly that any conclusions reached must be conditional--i.e., decisions are dependent upon a number of differing premises available to the decision-maker. Table 2-3 ranks the alternatives in terms of cost, effectiveness, and irreducible factors.* It should be noted that the irreducible-factor rankings could vary from those in Table 2-3, depending upon the relative weights assigned to each factor by the decision-maker.

*Irreducible factors are those which cannot be directly reduced to monetary terms; see section 2.3.3.

TABLE 2-3

RELATIVE RANKING OF ALTERNATIVE FACILITIES*

Most Favorable ⟶

Effectiveness Risk Index	Irreducible Factors (See §2.3.3)	Modified Cost of Ownership Over Ten-Year Period	
		Minimum Space	Doubled Space After Five Years
1A — 63.647	1B	3A — $2,752,200	3A — $4,287,340
1B — 63.647	1A	2B — 3,058,000	1B — $4,468,800
2A — 78.910	3A	1A — 3,433,500	1A — 4,574,000
2B — 78.910	2B	2A — 3,503,160	2B — 4,898,940
3A — 78.910	2A	1B — 3,622,800	3B — 5,439,940
3B — 78.910	3B	3B — 3,635,750	2A — 5,789,260

*1A = Bunker Hill at Pier F 2A = Building, Water-Level 3A = Battery Ashburn
1B = Bunker Hill at Pt. Loma 2B = Building, MILCON #P027 3B = Leased Building

(More complete descriptions of these facilities are given in section 2.2.2.)

2.3.1 Cost Ranking

Table 2-3 gives two cost rankings. Under "Minimum Space" the ranking is premised on an assumption that the minimum acceptable floor space, 35,750 square feet, will remain the same over the ten-year base of this study. From this standpoint, Battery Ashburn (Alternative 3A) including the required new construction is the least costly, followed in order by the MILCON building (2B) and the Bunker Hill at Pier F (1A).

In the second column the rankings are premised upon an assumption of a doubled floor-space requirement within five years. On this basis, Bunker Hill at either location and Battery Ashburn become nearly equal in cost, with the latter slightly lower.

However, these rankings could well lose much of their significance when considered in light of the suggested financial-support approach discussed in section 7. With this approach, and assuming that a 90 percent utilization of the facility can be achieved, annual support costs at NEL would be in the \$15,000-\$30,000 range, which considerably reduces the dollar differences among the alternative facilities. The dominating monetary factor would then be the acquisition cost (see Table 7-1, column 1). When viewed in this manner, the Bunker Hill at Pier F (first) and the leased building (second) far outrank the other alternatives.

2.3.2 Effectiveness Rankings

The analysis of section 4 indicates that the Bunker Hill at either location (Alternative 1A and 1B) would be an estimated 24 percent more effective than either of the remaining four alternatives in the identification and resolution of system uncertainties.

In view of the results summarized above, one question remains unanswered: How important is the 24 percent greater effectiveness of the Bunker Hill as a system facility as measured against the cost differential of the carrier and the lowest overall priced alternative? The results of section 5 can be reexamined to shed light upon this question. It was shown that for a system similar to those being considered for system-level evaluation, the quality of the facility made a difference of approximately \$7 million in the expected risk cost (\$16.12 million for a marginal facility minus \$8.58 million for an adequate facility). It is not suggested that the building and the hull alternates correspond to the "marginal" and the "inadequate" facilities of Table 5-1. However, the expected risk of \$8.58 million corresponding to the "adequate" facility in that figure might be used to adjust the modified risk totals of Table 4-1 to represent reasonable absolute as well as relative values. Thus, if the modified risk of \$64.6 million for the Bunker Hill is adjusted downward to equal the \$8.58 million of Table 5-1, then the \$80.4 million risk figure corresponding to the building alternates becomes

$$\left(\frac{80.4}{64.6}\right)(\$8.58 \text{ million}) \cong \$10.6 \text{ million.}$$

The expected savings offered by the Bunker Hill for each system would then be $10.6 million minus $8.58 million, or $2.0 million. For five systems evaluated within the facility, the expected savings would be five times this value, or $10 million.

The differential cost of retaining the Bunker Hill rather than the lowest total-cost building alternative (Battery Ashburn) is $493,800 (see Table 2-3) for a 10-year period. The trade-off is now evident between investment and return. The results indicate that, on the basis of total costs only, an additional facility investment of $493,800 by the Navy can be expected to yield a $10 million return in benefits to participating systems. This conclusion is, of course, valid only within the assumptions of sections 4 and 5, and is based upon the concept of expectation according to probability theory.

2.3.3 Irreducible Factors (See §3.3.4)

The most significant of the irreducible factors appears to be the immediate availability of the Bunker Hill. This availability factor is critical relative to the planning of system evaluations for projects in the development phase at the present time. Particularly in case of the integrated communication system, equipment is already being delivered to NEL for preliminary system evaluation purposes. All building alternatives will require a minimum of three years' lead time before occupancy. Thus the choice of a building alternate would mean a period of no facility prior to construction, or a transition period utilizing the Bunker Hill until completion of construction. The move from ship to building would create an awkward interruption of evaluation activity. In the case of Battery Ashburn (3A), the interval of interruption could be reduced if the existing 7,000 square feet of space were used to extend the move from ship to building over a longer period--say a year or more.

Other significant factors accounting for the rankings in Table 2-3 are expansion flexibility, the degree of approximation of the real environment in which the systems under evaluation will eventually be operated, and the cost-reduction potential which obtains to Bunker Hill through utilization of existing resources.

All of these factors combine to give Alternatives 1A and 1B a substantial lead in terms of irreducible factors.

2.3.4 Support of Basic Assumption

The basic assumption of this study is that a system evaluation facility is needed at NEL. An example in section 5 indicates the tremendous cost- and time-saving potential for large systems through investment in a system-level evaluation prior to operation evaluation (OPEVAL). It is axiomatic that such an evaluation requires a facility in which it can be performed. Section 5 therefore provides strong validation of the basic assumption.

2.3.5 Conclusions

From a technical standpoint, the Bunker Hill is an estimated 24 percent more effective than either new-building alternate. The cost of all six alternatives over a 10-year period is within 14 percent of their mean value, with Battery Ashburn (including new construction) being the lowest in cost. In the case of expansion after five years to twice the minimum required floor space, the cost of the Bunker Hill approaches equality with that of the Battery Ashburn because of the ship's surplus of unused space. Furthermore, the Bunker Hill is immediately available, while the building alternatives pose a 2- to 3-year delay period for funding and construction.

The results summarized in the previous paragraphs appear to indicate strongly the desirability, all things considered, of retaining the Bunker Hill and continuing its preparation as a facility for evaluating all complex Navy shipboard electronic systems both individually and, where practical, collectively. A study now in progress by the Bureau of Yards and Docks will determine whether or not the more desirable location south of Ballast Point can be prepared for the Bunker Hill within an acceptable cost.

3. TECHNICAL APPROACH

This section describes the approach taken for comparing the six alternative system-evaluation facilities described in section 2.2.

The cost effectiveness of a test facility is evaluated in terms of:

(1) Its direct cost in dollars; and

(2) Its effectiveness with respect to the degree of impact on the overall schedule and cost of ownership of the systems served.

In this study the cost of the facility was modified to include only those expenditures considered significant in evaluating differences in alternatives.

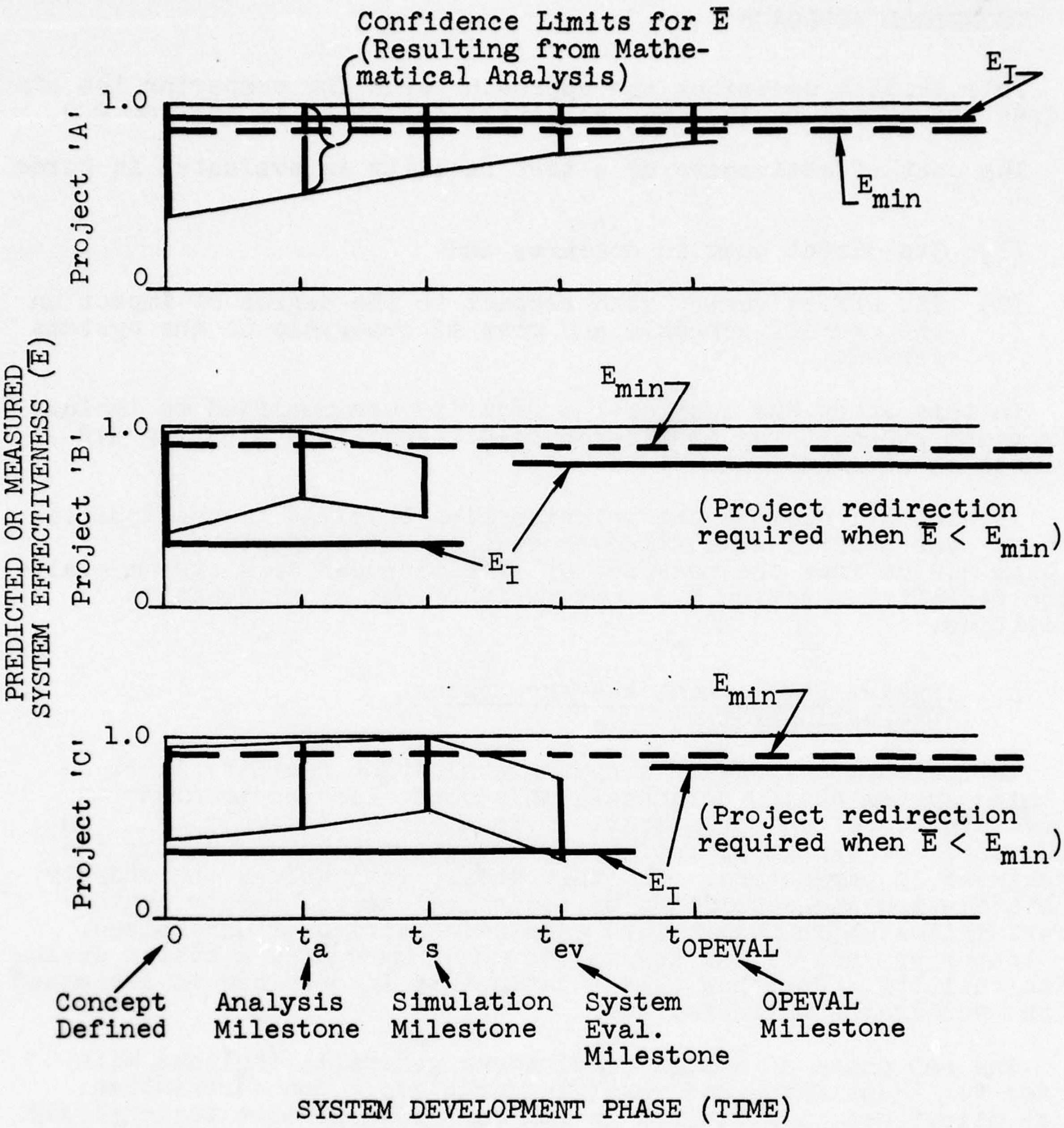
Section 3.1 defines the relationships involved in the application of system-level evaluation to development projects. Section 3.2 defines the measures of effectiveness of a system evaluation facility. Section 3.3 compares the cost of alternative facilities.

3.1 System Development and the System Evaluation Phase

The primary purpose of a system evaluation facility is to optimize system design parameters in a controlled environment as representative of an operational environment as is practical. In some facets of system operation, optimization involves simply the adjustment of parameters. In other areas, it involves the orderly identification and resolution of technological and requirements uncertainties which theretofore were unidentified or unresolved. The latter process is the key to the effectiveness of a system evaluation facility. Just how this relationship is obtained is discussed in the paragraphs which follow.

The R&D phase of system development generally includes milestones for identifying and resolving problems and uncertainties. These milestones, illustrated in Figure 3-1, represent successively more refined estimates of the system's intrinsic effectiveness, E_I. As shown in the figure, the range or spread of the estimated effectiveness, $\overline{E}$, reflects the confidence in the estimate. Another quantity, E_{min}, represents the minimum effectiveness considered to be acceptable for the mission requirements.

Each successive milestone in the R&D phase depicted in Figure 3-1 is aimed at narrowing the confidence limits of the effectiveness estimate. At the first point in time where the confidence limits do not include the required minimum effectiveness point, a significant change in project direction must be accomplished (Project "B", Figure 3-1). Either the system concept must be



E_I = Inherent effectiveness of system

E_{min} = Minimum acceptable system effectiveness

$\overline{E}$ = Predicted or measured system effectiveness at time t in R&D phase

FIGURE 3-1

MILESTONES IN SYSTEM DEVELOPMENT

changed to improve its capabilities or the minimum effectiveness requirements must be reassessed, with the possibility that a lower minimum requirement may be acceptable.

System-effectiveness confidence limits are narrowed as uncertainties are resolved. In general, the earlier each uncertainty is resolved, the lower is the overall program cost. The same is true for the time of delivery* of an acceptable system. Dollar savings thus achieved can be thought of by the procuring agency as a decrease in the cost of system ownership. Unresolved uncertainties pose a risk to the project in terms of increases in the overall cost of ownership of a system. This risk function exhibits a distinct discontinuity during operational evaluation (OPEVAL), as reflected in Figure 3-2. Prior to OPEVAL, the consequences of design uncertainties can be confined to design changes within an unreleased specification package. During OPEVAL, the resolution of uncertainties can result in design changes and corresponding tooling changes. Unresolved uncertainties subsequent to the OPEVAL period produce a significantly greater impact on a system in terms of both time and dollars, as Figure 3-2 illustrates. The nature of this impact is defined in the flow diagram of Figure 3-3.

During the early stages of system installation and utilization in the operational forces, an unresolved problem can result in costly retooling and retrofit. Furthermore, the Fleet's defense readiness may be significantly impaired during the retrofit period. The alternative to modifying the system is a choice to live with the system effectiveness degradation which results from the problem.

Two courses of action may be presented as a result of a decision to improve a system's effectiveness to an acceptable level. One action is to make improvements through equipment modifications, which involves a fixed or one-time cost. The other action involves improving the effectiveness through logistic or personnel changes, which generates recurring costs. An example of personnel changes would be where system effectiveness is improved by the establishing of a higher personnel level for maintenance.

3.2 Cost Effectiveness Criteria for a System Evaluation Facility

In section 3.1, the extent of system evaluation was related to the expected cost of ownership and delay in system delivery. These two relationships essentially define the effectiveness of a system evaluation facility. The delivery of an acceptable system can be delayed if the evaluation period is either too long or too short. In the former case, the resulting decrease in OPEVAL time and in the period of unacceptable operation following installation will not compensate for the extended evaluation time. In the latter case, the advantages of early physical delivery of the item will be negated by the extended OPEVAL and unacceptable-operation period.

*Delivery refers here to general acceptance of the system by the Fleet, rather than physical delivery.

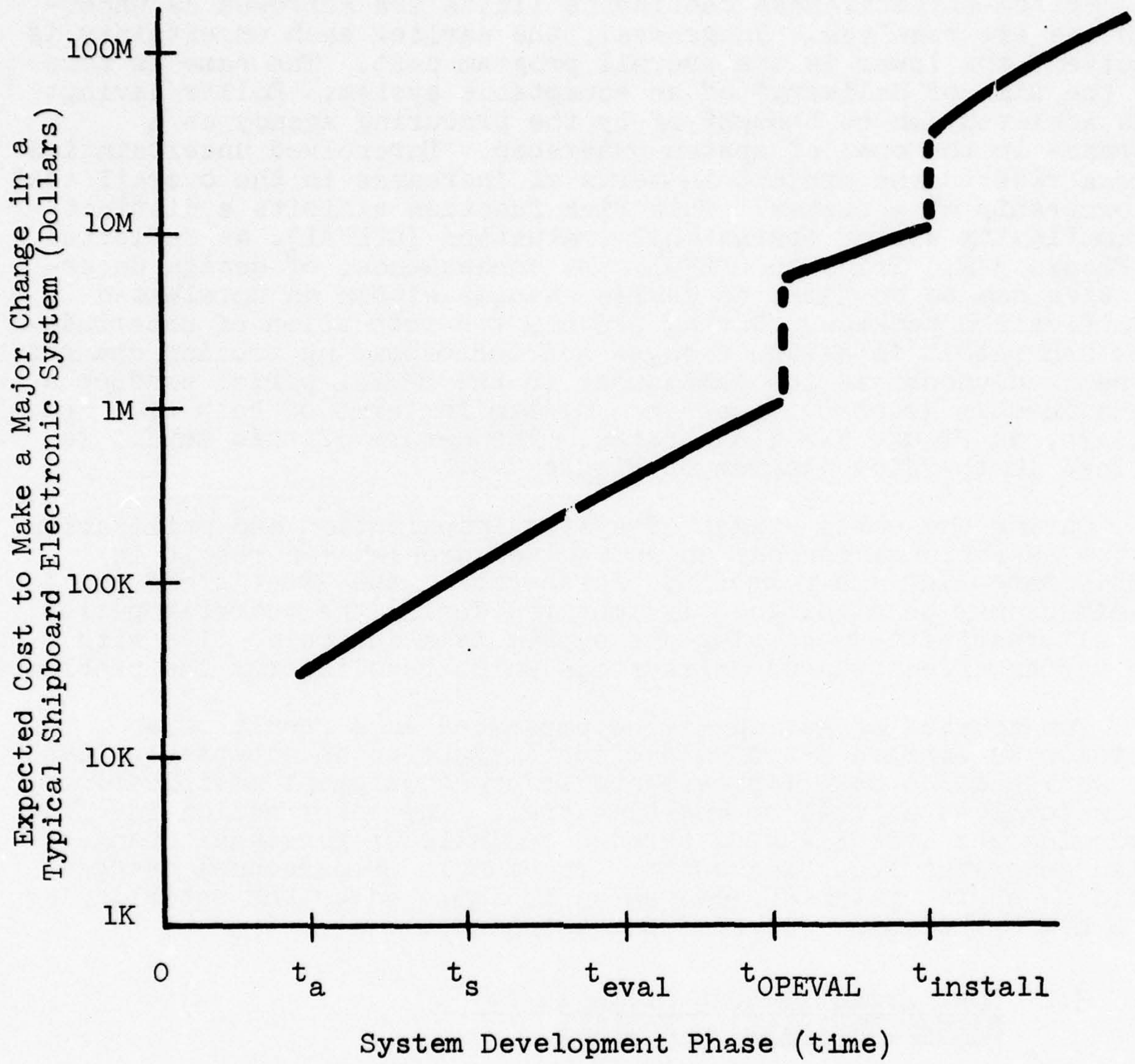


FIGURE 3-2

TIME-DEPENDENCE OF COST
OF EFFECTING SYSTEM CHANGE*

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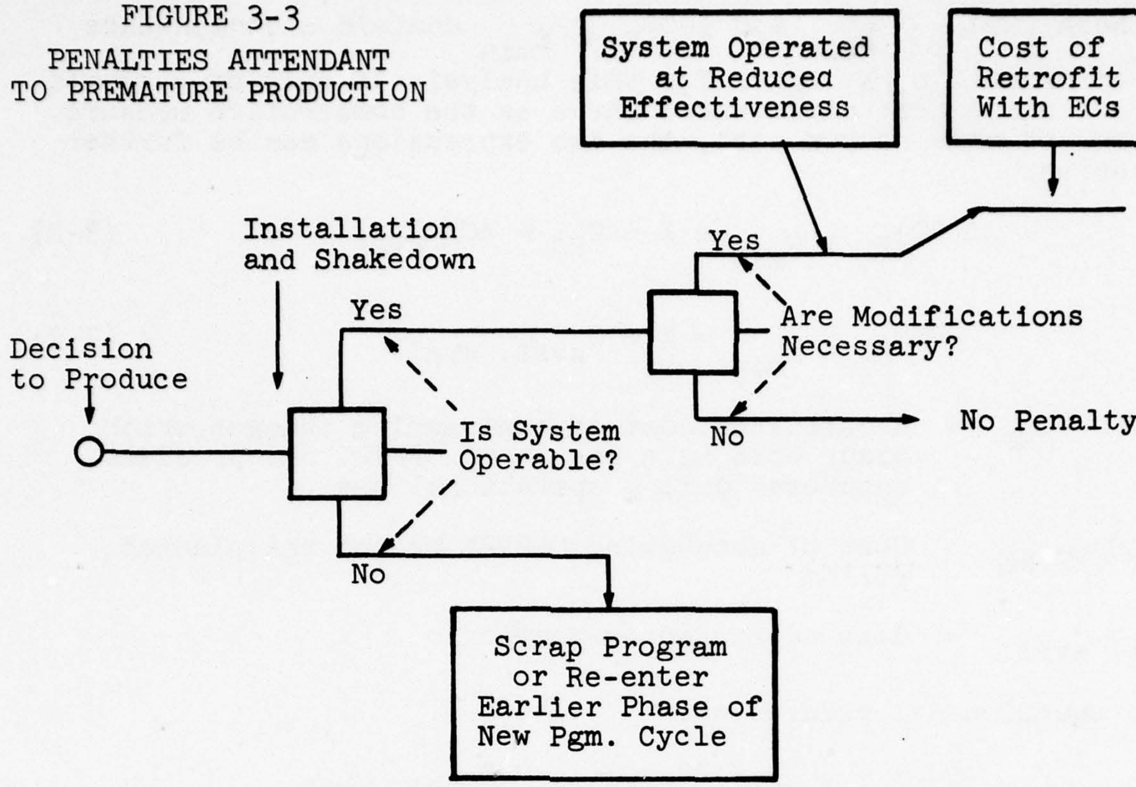
*This graph presents a hypothetical situation. No specific data have been gathered to substantiate it.

FIGURE 3-3

PENALTIES ATTENDANT TO PREMATURE PRODUCTION



Time delays cannot be readily expressed in terms of dollars unless some rather restricting assumptions are invoked. Therefore, both the cost of system ownership (CO) and delay in system delivery (DD) will be used as measures of the effectiveness of the system evaluation facility.

The expected cost of ownership of a system (which may or may not utilize the system facility) can be expressed as

$$\Delta(CO) = (CO)_{E_I \geq E_{min}} - (CO)'_{E_I \geq E_{min}} \tag{3-1}$$

where $\Delta(CO)$ = Expected influence on total system cost of ownership of a given amount of system-level evaluation

$(CO)_{E_I \geq E_{min}}$ = Total cost of ownership without a system evaluation, but for a delivered product whose inherent effectiveness equals or exceeds the minimum requirement

$(CO)'_{E_I \geq E_{min}}$ = Total cost of system ownership with an adequate system evaluation*

*The assumption was made here that an adequate system evaluation is one which will result in a normal OPEVAL period and insignificant engineering changes (ECs) to the installed systems.

Both $(CO)_{E_I \geq E_{min}}$ and $(CO)'_{E_I \geq E_{min}}$ contain a common-base cost of ownership, X, which for this analysis is only of academic interest since cost differences serve as the comparative measure. In terms of this common cost, the two expressions can be further defined as:

$$\Delta(CO)_{E_I \geq E_{min}} = X + C_{EC} + \Delta C_{OPEVAL} \tag{3-2}$$

$$(CO)'_{E_I \geq E_{min}} = X + C_{syst.\ eval.} \tag{3-3}$$

where C_{EC} = Accumulated cost of engineering changes which occur both as a result of OPEVAL and problems uncovered during operational use

ΔC_{OPEVAL} = Cost of conducting OPEVAL beyond the planned period

$C_{syst.\ eval.}$ = Cost of system evaluation

Thus, equation 3-1 reduces to:

$$\Delta(CO) = \left(C_{EC} + \Delta C_{OPEVAL}\right) - C_{syst.\ eval.}$$

The delay in delivery of an acceptable system can be similarly treated (this time omitting the subscript $E_I \geq E_{min}$, which still applies):

$$\Delta(DD) = DD - DD' \tag{3-3}$$

where $\Delta(DD)$ = Expected influence on system delivery time of a given amount of system-level evaluation

DD = Delay in delivery of an acceptable system which has not undergone a system evaluation

DD' = Delay in delivery of an acceptable system with an adequate system evaluation

The factors DD and DD' can each be expanded in terms of a common time lapse, T, plus delays unique to each:

$$DD = T + \Delta T_{EC} + \Delta T_{OPEVAL} \tag{3-4}$$

$$DD' = T + T_{syst.\ eval.} \tag{3-5}$$

where ΔT_{EC} = Accumulated time of interruption of fleet-readiness of a ship while engineering changes are being identified and installed; divided by the number of ships involved

ΔT_{OPEVAL} = Delay in delivery caused by stretch-out of OPEVAL

$T_{syst.\ eval.}$ = Net amount of development time attributed to adequate system evaluation, including changes and redirection resulting therefrom

In examining the cost effectiveness of a system evaluation facility, the pro-rated direct cost (see section 6) of the evaluation for a given system must be compared with the potential impact upon total system cost of ownership, ΔCO, and delay in delivery, ΔDD, of an acceptable product. The latter measures of effectiveness, as previously defined in equations 3-1 and 3-3, are identified as the risks in the decision matrices of sections 4 and 5.

3.3 Development of Facility Cost Comparisons

The cost structure which was formulated for comparison of the alternative facilities is shown in Figure 3-4. Acquisition cost is that associated with making a facility available and ready for use, and is a one-time fixed amount occurring at the beginning of the term of ownership. Operation cost includes the funds necessary to operate, maintain, and administer the facility, and is calculated on a per-annum basis.

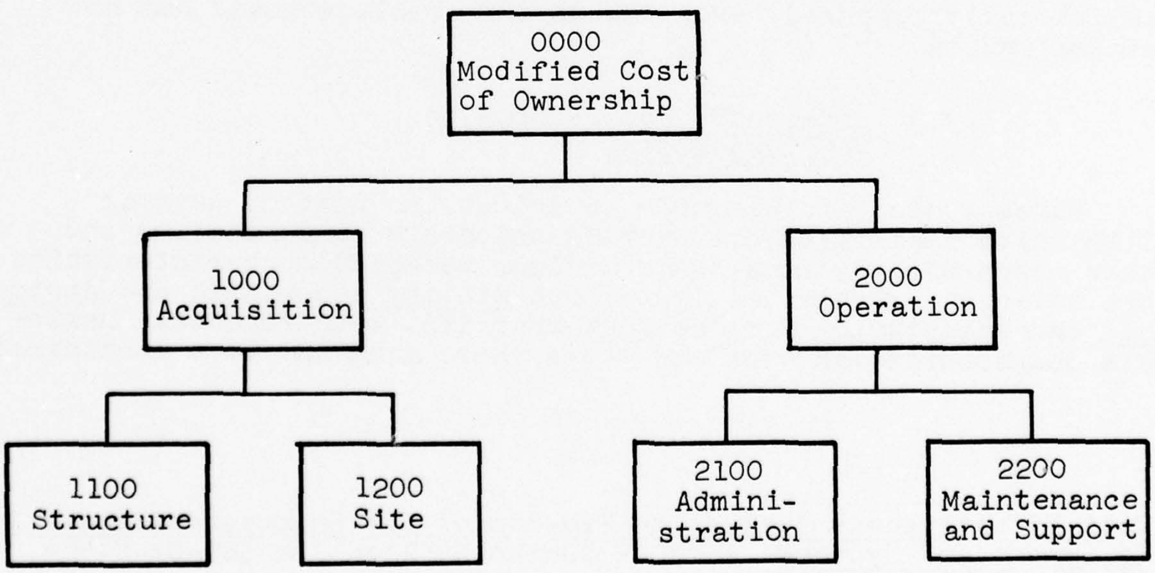


FIGURE 3-4
COST STRUCTURE

3.3.1 Basis for Estimating Facility Costs

The procedures described in a recent ARINC Research report* served as a basis for estimating facility costs. These procedures were originally derived to evaluate the cost effectiveness of shipboard electronic equipment; however, they have equal applicability to a system test facility.

In comparing the alternative facilities, only those costs occurring in the future are considered of practical value; all past expenditures are considered as sunk costs.† In this study, costs are examined for the ten-year period from June 1966 to June 1976. The decision to examine costs over a ten-year period was somewhat arbitrary; however, a twenty-year interval was also examined to ensure that no significant alternative-selection differences occurred. The shorter interval was favored because, from a management planning viewpoint, the visibility beyond a ten-year period taxes the ability to quantitatively assess the requirements for a system facility.

3.3.2 Modified Cost of Ownership

A special effort was made to minimize the possibility of biasing any of the alternatives. Therefore a cost-analysis method was developed which is equally meaningful whether used on a ship, hull, building, or battery. Likewise, even though the incremental costs were not precisely determinable, estimates were made based on the same logic for each alternative. With this approach the modified cost of ownership of the various alternatives could be realistically compared, even though the absolute costs had not been estimated.

3.3.3 Effect of Requirements on Facility Costs

Since a decision was made to select the best of several alternative facilities for testing shipboard communication and other electronic systems, some minimum acceptable characteristics were selected. Table 2-1 lists both minimum acceptable and desirable characteristics for the most important requirements. Desirable characteristics over and above these minimums were considered

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*Cost-Effectiveness Evaluation Procedures for Shipboard Electronic Equipment and Systems, ARINC Research Publication 509-01-2-564, February 1966, two volumes.

†This principle is treated in detail in Principles of Engineering Economy, E. L. Grant and W. G. Ireson, Ronald Press Co., N. Y., Fourth Edition, 1964.

as irreducible factors. In this way the basic calculations are partially normalized, but the irreducible factors (e.g. expansion flexibility) are still considered in the final decision.

3.3.4 Irreducible Factors

Although most of the differences between alternative facilities can be expressed in terms of cost, some differences relevant to the decision cannot be so reduced. The more significant irreducible factors for the alternative facilities are listed in this section.*

3.3.4.1 Bunker Hill at Pier F

(1) Facility available for immediate use with a short lead time for equipment installation.

(2) Mobility: can be moved to any location in a waterway.

(3) Can be used as a portable, emergency communication station

(4) Can be used as a ship's security laboratory.

(5) Can be used as a shipboard-noise analysis laboratory.

(6) May be a hazard to the operation of aircraft from NAS, North Island, and seaplane lanes.

(7) Industrial safety hazard greater aboard ship.

(8) Working conditions may be only marginally acceptable.

(9) Psychological advantage of shipboard environment for personnel accustomed to ships.

(10) Can be used as an operation/maintenance training facility, both generally and as proposed by the O-in-C Naval Radio School, NTC, San Diego.

(11) Facility is reportable under the Navy Cost Reduction Program to the Secretary of Defense under the category of utilization of surplus materials.

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*Such factors a "lead time" to establish and implement a Military Construction Project (MILCON) may be borderline and partially considered as reducible and partly as irreducible.

3.3.4.2 Bunker Hill Adjacent to East Shore of Pt. Loma

(1) Facility available for immediate use with a short lead time for equipment installation.

(2-11) Same as foregoing items 1-11 (section 3.3.4.1), except item 6 not applicable.

(12) Some delay and expense involved in preparation of site. However, delay would be slight during transit to Pt. Loma since operation could continue at Pier F until new site is ready.

(13) Berthed close to the cliffs south of Ballast Point, it will be less conspicuous than at Pier F.

(14) Productive use will be made of valuable, unused harbor property.

(15) A prior claim will be established on valuable, unused harbor property.

(16) Better physical control of the facility is afforded by location as a part of the Pt. Loma reservation. Better fire protection and emergency maintenance support, etc.

3.3.4.3 West Side of Pt. Loma, Water-Level Building

(1) Proximity to water partially approximates the radiation ground plane of a ship.

(2) Access road has steep gradient.

(3) Industrial safety features can be built in.

(4) Long lead time to complete building (at least three years).

(5) Cannot meet Fleet School or Communications Security support requirements.

(6) New building has a high aesthetic value.

3.3.4.4 Compound Building

(1) Plans are to use part of a building presently under a MILCON project.

(2) Long lead time to complete building (at least three years).

(3) Designated portion of building (35,750 ft^2) can be designed for specific use.

(4) Forms integral part of present laboratory.

(5) New building has a high aesthetic value.

3.3.4.5 Battery Ashburn

(1) 7,000 ft^2 could be made available for immediate use.

(2) Remaining 28,750 ft^2 will require long lead time to build.

(3) Secure spaces presently available.

(4) Present occupants must be moved elsewhere.

(5) Cannot meet Fleet School or Communications Security support requirements.

(6) Integration of existing space with new construction poses practical problems in facility design and operation.

(7) New construction would be adjacent to unrestricted public thoroughfare.

3.3.4.6 Leased Building

(1) Short-term lease allows flexibility to discontinue or move facility.

(2) Low acquisition costs.

(3) Location may be inconvenient.

(4) Security specification may be difficult to meet.

(5) Least accessible for material and personnel movement.

(6) May pose difficult and expensive problems of data linkage to existing NEL facilities.

(7) Cannot meet Fleet School or Communications Security support requirements.

(8) Proximity to public thoroughfares.

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4. RELATIVE EFFECTIVENESS OF FACILITY ALTERNATIVES

The relative effectiveness of the six alternative facilities was the subject of considerable study. The basic factors in the study were the evaluation objectives for which the facility is being planned, and the projected risks associated with each objective. As explained in section 3, each risk has an influence on the ownership of the systems which are likely to be evaluated at the facility.

Table 4-1 gives a comprehensive analysis of the evaluation objectives and risks, including an indication of the adequacy of each alternative facility with respect to the system evaluation objectives. (The table follows page 4-6.)

4.1 General Assumptions

In the decision model described in section 4.2, certain general assumptions have been made; these assumptions are summarized below to assist the reader in interpreting the information in Table 4-1.

The numerical information in the table is not traceable to specific references or specific contact with technical personnel. Instead, they represent ARINC Research Corporation's best judgment, based on all available information (gained primarily from interviews).

During the period of interviewing and data collection which preceded the analysis, provision was made for treating the effectiveness of each of the six alternate facilities individually. However, when the information was assembled and analyzed, it was found that from a technical standpoint the six alternatives could be conveniently grouped into two categories: "hull"and "building". With the assumed minimum requirements* set forth in section 2.1, the differences in technical suitability between the Bunker Hill (hull) at Pier F (1A) or south of Ballast Point (1B) were found to be insignificant. Similarly, the differences in technical suitability between all the remaining (building) candidates were found insignificant. Table 4-1 therefore categorizes the alternative facilities as either hull or building types. Comparison within these two categories must be in terms of either direct costs or irreducible factors.

The first impression during preliminary evaluation is that the opportunity to utilize a carrier-type hull from the reserve fleet would offer an overall environment of unquestionable realism from a system evaluation standpoint. However, in attempting to

*The cost of providing these same minimum requirements in each case is included in the cost comparisons of section 6.

isolate and study these benefits in greater detail, the advantages of the ship become less pronounced. Some of the leavening considerations are as follows:

(1) The carrier hull and compartment configuration is not representative in all respects of the configurations for which many of the new shipboard systems are being planned. In addition, the carrier hull superstructure cannot be patterned to that of projected ship superstructures without incurring unreasonable costs. However, the <u>Bunker Hill's</u> compartmentation approximates most hulls except for command centers. These centers could be duplicated on the hangar deck with a closer approximation of reality than can be achieved in a shore building.

(2) The electronic suit aboard the <u>Bunker Hill</u> hull is neither complete enough nor sufficiently updated to be representative of the "other system" electromagnetic environment projected for systems currently in development.

(3) The use of the hull as a means of identifying and studying the "rusty bolt" problem* should be classed as experimentation rather than system-level evaluation. Nevertheless, the hull does provide a realistic mechanism in establishing a noise floor in the presence of a system installation. Therefore, there is good reason to evaluate noise components and validate prediction models in actual system-level operation.

(4) Treatment of the personnel environment necessary for operation and maintenance evaluation can be made surprisingly realistic in any building. A good example is the FAAWTC operation adjacent to NEL.

In spite of the aforementioned practical problems, certain advantages of conducting the system evaluation aboard an actual hull, such as the <u>Bunker Hill</u>, must be recognized. These can be itemized as follows:

(1) A significant value can be attached to the capability in the <u>Bunker Hill</u> for installing portions of a system in a compartment and using cable runs (signal and power) somewhat representative of a realistic installation.

(2) The evaluation of security problems (particularly the red-black problem) aboard the compartmented <u>Bunker Hill</u> would be more valid than a comparable study in a shore-based building.

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*"Rusty bolt" problem: the re-radiation of harmonics by the nonlinear steel joints under parasitic excitation.

(3) With respect to the human aspects of a given system, the Bunker Hill offers a much more realistic "duty" environment than does a building--particularly as the training phase of evaluation is reached for each system.

(4) Naturally present are problems associated with piping, cabling, ducting, bulkhead structures, and other shipboard accessories; in practice these physical items would tend to be sacrificed in any "budget squeeze" in a shore building.

It has been assumed in this section that to meet the minimum RF requirements for communications systems, both Bunker Hill alternatives (1A and 1B) would be augmented with an antenna installation on the west shore of Pt. Loma covering VHF and higher frequencies. This installation would be functionally connected to the ship over a multi-channel microwave link. Thus the communications system aboard the Bunker Hill could be in complete contact with the First Fleet operating off the West Coast through either the antenna augmentation or through the live circuit of FAAWTC via microwave.

Other assumptions of this study are (1) Bunker Hill will not be returned to the Reserve Fleet, and (2) disposition costs will be offset by surplus-item and salvage returns. However, it should be recognized that disposition costs will not be affected by these returns on an appropriation basis, in that the returns are not credited to the account burdened by disposition costs. Actually there is reasonable expectation that the sale and salvage returns would exceed disposition costs. For this reason the second assumption at the beginning of this paragraph has been applied in the analysis.

4.2 Decision Model

Relative-effectiveness considerations for the six alternative facilities have been reduced to the decision matrix of Table 4-1. Column headings of the matrix are described in the following paragraphs. In arriving at the numerical entries in this matrix, consideration has been limited primarily to that family of shipboard electronic systems which characterize the new era in Navy operations. Representative of this category are the integrated communications system, the tactical data systems, the intelligence systems, and the strategic data systems. Among the common properties of these systems are computer-centered operation, with high-volume digital information flow; and the fact that each system will eventually interface with all of the others.

Referring to Table 4-1, the first column contains the three basic components of system effectiveness--Performance, Availability, and Utilization.* The second column presents a numerical breakdown

*The numbers before and after these effectiveness components will be explained later.

of each of these three components. The third column contains a statement of an evaluation objective appropriate to the class of systems for which system evaluation is planned. The fourth column, "System State", contains a weighting factor representing the probability (relative to other effectiveness subcategories) that a new system concept will have a significant problem area or uncertainty attendant to its development. The numbers for this column were derived by the process of starting with the three major components of effectiveness (Performance, Availability, and Utilization) and apportioning weighted numerical values (adding to unity) among them according to best engineering assessment of pertinent information. The apportionment given in the table reflects the judgment that system-design problems can be expected to occur with the following relative probabilities:

Performance — 0.5

Availability — 0.2

Utilization — 0.3

For example, performance problems are 0.5/0.2 = 2.5 times as likely to occur as are availability problems.

Some of the experience upon which these assignments are based is embodied in the case histories constructed by ARINC Research for NEL under the present contract.* Other experience accrued from interviews with representatives of OPDEVFOR, EMEC, and OEG. The value assigned to each of the three major components was similarly apportioned among their subcomponents. This apportionment process was chosen to avoid serious biasing of the remainder of the matrix.

The fifth column, "Probability of Uncertainty Remaining", contains estimates conditional on the system state number. This number represents the probability that the problem of uncertainty (given that one exists) would not, through the due course of subsystem development, be adequately identified and resolved.

The sixth column, "Risk Category", contains an index representing the magnitude of consequences resulting from failure to properly identify and resolve a problem area or uncertainty associated with each evaluation objective, considered one at a time. Five levels of risk are provided, corresponding to powers of the base five. For example, the number 1 in this column refers to a risk of five to the first power. Similarly, the number 5 refers to a risk of five to the fifth power. This stratification of risk is intended to cover the range of consequence from the installation of simple modification kits in the field to the removal of a ship from the Fleet for overhaul. In terms of

*ARINC Research Corp., Role of Test and Evaluation in System Development, Publication W5-404-TN001-1, November 1965.

dollars, this risk stratification might be expressed according to the following equivalents table:

Risk Category	Relative Risk	Dollar Equivalence	Cost of Design and Installation of:
1	5^1	$\$ 0.1 \times 10^6$	Simplest modification kit
2	5^2	0.5×10^6	↓
3	5^3	2.5×10^6	
4	5^4	12.5×10^6	
5	5^5	62.5×10^6	Major modification requiring overhaul availability

Obviously, dollars are not the only classification of risk. Two other classifications are important: the time delay factor (see section 3) and the detrimental effect on Fleet readiness which accompanies any modification program. The latter factor is also significant as an element of surprise in experiencing degraded performance when the system is first called upon to perform its mission. The latter two classifications have been considered in each table entry and have been subjectively translated into terms of dollars. For example, a problem for which the solution is low in cost but significant in terms of downtime of the ship and degradation in Fleet readiness will be assigned a risk level considerably higher than that based on cost alone.

Column seven is subdivided into two columns representing "hull" and "building" type facilities. The entries in these columns represent the probability of the indicated system facility alternate providing adequate identification and resolution of the corresponding system uncertainty, assuming each alternative satisfies the minimum requirements of section 2.2.

The eighth column, "Modified Risk Index", contains entries obtained from other numerical entries in the table according to the following formula:

$$\begin{aligned}\text{Modified Risk} &= \text{System State} \times \text{Probability of Problem Remaining} \\ &\quad \times (1 - \text{Adequacy of Facility Alternate}) \\ &\quad \times 5 \exp(\text{Risk Category}).\end{aligned}$$

The reader is cautioned against attaching any significance to the <u>absolute value</u> of any modified risk entry or to the summations at the bottom of Table 4-1. These numbers have <u>relative</u> significance only.

The right-hand column, "Qualifying Remarks", indicates the reasoning underlying the choice of numbers for each entry in the table.

4.3 Conclusion

The modified risk summation at the bottom of Table 4-1 is presented as an index of the relative effectiveness of the six alternate system facilities. Simply speaking, these numbers represent a figure-of-merit rating for each facility according to the facility's ability to impact on the life cycle of a typical complex shipboard electronic system.

5. OVERALL NEED FOR EVALUATION

This section contains an elementary exercise in decision theory incorporating the experience factors used in the relative effectiveness matrix (Table 4-1). However, in this section the problem is reformulated into a framework (Table 5-1) which addresses the question of whether or not system-level evaluation is justified. The analysis is based primarily on the categorization of a system state into one of three groups, weighted from experience. The three groups define the probable acceptability of a new system configuration prior to OPEVAL and appear as horizontal rows in Table 5-1.

Two basic actions (test or no-test) refer to whether or not a system-level evaluation is performed with the system. The "no test" entries correspond to the consequences during OPEVAL and subsequent to installation. The "test" entries correspond to each of three possible test results (accept, modify and retest, and reject). Again the consequences of each outcome during subsequent OPEVAL and installed operation are given. In each case, the consequences are stated in terms of dollars and delay time. An expectation (or mean value) for each consequence is obtained by multiplying the dollar or time figure by the system state probability, and--for "test" only--by the probability of adequate system evaluation.

The summation of expected dollar and delay-time risks at the bottom of the figure then allows a comparison of consequences, on a probable risk basis, corresponding to the selected action.

The numbers in Table 5-1 representing cost and delay time are calculated from the assumed conditions of Table 5-2. A system development was structured in this table which could be typical of the sophisticated Navy systems now under procurement or planned for the near future.

The results of the example, as indicated at the bottom of Table 5-1, would indicate that severe consequences in both dollars and delivery time can be expected when any significant compromise is made in the application of a system evaluation. This can be seen by comparing the expected risk cost of not performing a system evaluation ($31.69 million) with the expected risk cost of an adequate evaluation ($8.58 million). This conclusion would not necessarily hold for systems of low complexity or small production quantity.

Estimate of System State	ACTION: NO TEST Consequence	Weighted $\frac{\Delta(CO)}{10^6}$ Dollars	Weighted $\Delta(DD)$ Years	Result of Test	Adequacy of System Evaluation: Adequate	Marginal	Inadequate	ACTION: TEST Consequence	$\frac{\Delta(CO)}{10^6}$ Dollars: Adequate	Marginal	Inadequate	$\Delta(DD)$ Years: Adequate	Marginal	Inadequate	Weighted $\frac{\Delta(CO)}{10^6}$ Dollars: Adequate	Marginal	Inadequate	Weighted $\Delta(DD)$ Years: Adequate	Marginal	Inadequate
ACCEPTABLE (0.2)	No additional cost or delay incurred			Accept	1.0	1.0	1.0	Test	0.8	0.6	0.4	1.0	0.67	0.33	0.16	0.12	0.08	0.2	0.13	0.07
								No additional time or dollars	0	0	0	0	0	0						
				Modify and Retest	0	0	0	Test	1.1	0.8	0.6	1.5	1.0	0.5	-	-	-	-	-	-
								N.A.			N.A.									
				Reject	0	0	0	Test	0.8	0.6	0.4	1.0	0.67	0.33	-	-	-	-	-	-
								N.A.			N.A.									
MARGINAL (0.5)	OPEVAL extended by 12 mo	0.1	0.5	Accept	0.2	0.6	0.8	Test	0.8	0.6	0.4	1.0	0.67	0.33	3.11	9.3	12.28	0.40	1.10	1.32
	ECs (minor) to prototype system, causing inactive periods within OPEVAL	2.5	0.25					Extended OPEVAL (18 mo)		0.3			1.5							
	Approval by OPTEVFOR followed by production and installation in Fleet							ECs in prototype equip.		5.0			0.5**							
	ECs to installed systems (to resolve residual problems)	12.5	0.50					ECs in prod. equip.		25.0			1.0							
				Modify and Retest	0.8	0.3	0.2	Test	1.1	0.8	0.6	1.5	1.0	0.5	2.67	0.95	0.62	1.0	0.30	0.15
								Extended OPEVAL (6 mo)		0.3			0.5							
								ECs in devel. model		0.25			-							
								ECs in prototype		5.0			0.5**							
				Reject	0	0	0	Test	0.8	0.6	0.4	1.0	0.67	0.33	-	-	-	-	-	-
								Redevelop including minimum retest (6 mo) and		7.5			2.0							
								OPEVAL (6 mo)	0.8	0.5	0.4		1.0							
UNACCEPTABLE (0.3)	OPEVAL extended by 18 mo	0.09	0.45	Accept	0	0.2	0.6	Test	0.8	0.6	0.4	1.0	0.67	0.33	-	3.35	1.0	-	0.28	0.60
	ECs (major) to prototype system, causing inactive periods within OPEVAL	1.5	0.3					Extended OPEVAL (18 mo)		0.3			1.5							
	Conditional approval** by OPTEVFOR followed by production and installation in Fleet	-	-					ECs in prototype equip.		5.0			0.5							
	ECs (major) to installed systems	15.0	0.6					ECs in prod. equip.		50.0			2.0							
				Modify and Retest	0	0.6	0.3	Test	1.1	0.8	0.6	1.5	1.0	0.5	-	1.88	0.89	-	1.23	0.51
								ECs in devel. model		0.25			0.5							
								Retest*	0.8	0.6	0.4	1.0	0.67	0.33						
								Extended OPEVAL Redevelop		0.2			1.0							
				Reject	1.0	0.2	0.1	Test	0.8	0.6	0.4	1.0	0.67	0.33	2.64	0.52	0.25	0.12	0.22	0.1
								Redevelop including minimal retest and OPEVAL		7.5			2.0							
										+0.5			+1.0							
	$\sum$	= 31.69 (Million Dollars)	2.60 (Years)											$\sum$	8.58	16.12	15.12	1.72	3.26	2.75
															(Million Dollars)			(Years)		

*This does not include the cost penalty associated with tieing up the host ship(s) during the extension.

**OPTEVFOR is constrained to not reject a major system.

$\Delta(CO)$ = dollar impact on system cost of ownership

$\Delta(DD)$ = delay impact on delivery of acceptable system to Fleet

TABLE 5-1

DECISION MATRIX ILLUSTRATING IMPACT OF SYSTEM EVALUATION ON COST OF OWNERSHIP AND DELIVERY DATE

TABLE 5-2

COST AND DELAY COMPONENTS ASSUMED FOR EXAMPLE
(See Table 5-1)

EVALUATION FACILITY (COST)

Physical structure	=	$400K (3 systems)	=	$167,000
Manpower at 15-man level	=	$375K (3 systems)	=	125,000
Instrumentation			=	200,000
Subsystem personnel at 10-man level (per system)	=	$250K (per system)	=	250,000
			Total	775,000

OPEVAL

Assume 6-month planned OPEVAL

2 years for marginal system accepted during system evaluation

12 months for unacceptable system accepted during system evaluation

Assume OPEVAL requires technical crew of 10 men at $20K per man per year

6 months stretch-out = $100,000

18 months stretch-out = $300,000

(Not including cost of ship out of operational state)

SYSTEM

Assume

- 20 copies to be delivered at approximately $5M per copy
- Normal R&D phase costs $30M
- Redevelopment costs are 25 percent of original R&D ($7.5M)
- Cost of engineering changes (ECs) after installation is 25 percent of original cost, or $1.25M per system
- Cost of engineering changes for marginal system prior to production adds 5 percent to original cost (for redesign, retooling, and minor parts reordering), or $0.25M per system
- Cost of engineering changes for unacceptable system after installation ($50M)

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6. COST COMPARISON

As stated in section 3, cost-of-ownership techniques were used in organizing and presenting the data; however, since only those costs significant to a decision were considered, the results are labeled "Modified Cost of Ownership". After a decision is made and an alternative selected, it may be wise to continue and develop a Total Cost of Ownership using the previously developed techniques. This would require a greater depth of detail in the gathering and analysis of additional data. The results of a cost comparison of the six alternative system-test facilities are given in Table 6-1.

6.1 Cost Details

On pages 6-3 through 6-7 the costs associated with the acquisition and operation of each alternative facility are explained in further detail. These costs are representative of the most significant expenditures that may influence a decision. Some costs, such as the equipment-installation costs common to all alternatives, have not been included. Most of the items are common to all of the facilities (e.g. utilities, parking, etc.). However, some are unique to one or two alternatives, such as cathodic protection, dehumidification, and conductive roofs.

Since most of the costs are estimates they have been rounded off to the most significant digit. All known sources of relevant information were surveyed, and the data were carefully examined for validity. No attempt was made to establish a confidence level for each item since there was insufficient time to examine all the design details of each alternative. It is suggested that in cases where the reader questions an input, a new estimated cost be inserted and examined for significance. If it appears significant, verification in more detail may be in order.

6.2 Summary of Facility Costs

For each of the candidate facilities, Table 6-1 summarizes the cost of acquisition and operation over a ten-year period (June 1966-June 1976). As explained in section 3.3.1, funds expended prior to June 1966 (sunk costs) have not been considered. The structure acquisition (1100) is low for alternatives 1A and 1B (Bunker Hill) because the basic structure exists and a compartmentation set-up is all that is required on the hangar deck. Similarly, since 3B is a leased building the original costs are low. The cost of lease payments over a ten-year period are shown as a double entry under 2200/3B. Note that when costs alone are considered over a ten-year period, the order of preference is 3A, 2B, 1A, 2A, 1B, and 3B. However, the facility effectiveness and irreducible factors will necessarily influence the final decision.

TABLE 6-1

COST OF ALTERNATIVE TEST FACILITIES, JUNE 1966 THROUGH JUNE 1976

Facility (§2.2.2)	Acquisition (1000)		Operation (2000)		Total
	Structure (1100)	Site (1200)	Admin-istration (2100)	Mainte-nance and Support (2200)	
	$	$	$	$	$
Bunker Hill, Pier F (1A)	325,000	34,500	1,000,000	2,084,000	3,443,500
Bunker Hill, Pt. Loma (1B)	325,000	1,213,800	200,000	1,884,000	3,622,800
Water-Level Bldg. (2A)	1,191,500	688,910	200,000	1,422,750	3,503,160
Compound Bldg. (2B)	1,191,500	243,750	200,000	1,422,750	3,058,000
Battery Ashburn (3A)	896,500	232,950	200,000	1,422,750	2,752,200
Leased Bldg. (3B)	350,000	5,000	1,000,000	1,422,750 +858,000*	3,635,750

*Ten-year lease cost.

6.3 Expansion Costs

The effect on cost of expanding the system evaluation facility to double size after five years is illustrated in Figures 6-1 and 6-2. Compared in this regard are the Bunker Hill at Pier F and the Battery Ashburn. (These alternatives were selected because the former represents the lowest cost of expansion and the latter represents the lowest-cost building.)

Figure 6-1 shows comparative costs over a ten-year period assuming no expansion in facility size; Figure 6-2 reflects an expansion to double size after five years. It can be seen that the cross-over point of cumulative cost shifts from slightly more than 5 years to almost 9 years if expansion occurs.

COST DETAIL
ALTERNATIVE NO. 1A
BUNKER HILL, PIER F

Structure (1100)

1.	Designing and planning	$ 75,000
2.	Construct hangar deck compartments	200,000
3.	Activate compartments	25,000
4.	Secure area 5000 ft^2 @ $5/$ft^2$	25,000
		$325,000

Site (1200)

1.	Prepare Pier F for light vehicular traffic	$ 8,000
2.	Connection for water main	4,000
3.	Parking lot, 100 cars	18,500
4.	Connection for sewerage line	4,000
		$ 34,500

Administration (2100)

10 civilians @ 10K	$100,000

Maintenance and Support (2200)

1.	Janitorial service (4 @ 6K)	$ 24,000
2.	Upkeep and painting	20,000
3.	Repairs	20,000
4.	Cathodic protection	10,000
5.	Maintenance supplies	10,000
6.	Utilities	
	Electricity, water, sewerage, gas	40,000
	Telephone	14,400
7.	Operation of shuttle boat	20,000
8.	Guards (5 @ 8K)	40,000
9.	Dehumidification maintenance	10,000
		$208,400

COST DETAIL
ALTERNATIVE NO. 1B
BUNKER HILL, E. SIDE PT. LOMA

Structure (1100)		
Same as Alternative No. 1A		$ 325,000
Site (1200)		
1. Prepare berth		$1,000,000
2. Pedestrian walkway		50,000
3. Parking lot, 100 cars		18,500
4. Bring in Utilities		
a. Electrical		
	Cable	42,400
	Overhead reinforcement	12,800
	Substation	70,600
b. Water		4,900
c. Sewerage		4,000
d. Communications		10,600
		$1,213,800
Administration (2100)		
2 civilians @ 10K		$ 20,000
Maintenance and Support (2200)		
Same as Alternative 1A		$ 208,400
Less cost of shuttle boat		- 20,000
		$ 188,400

COST DETAIL
ALTERNATIVE NO. 2A
WEST SIDE WATER-LEVEL BLDG.

Structure (1100)

1.	Standard area, 30,750 ft^2 @ \$30/ft^2	\$ 922,500
2.	Secure area, 5000 ft^2 @ \$45/ft^2	225,000
3.	Special conductive surface on roof	44,000
		\$1,191,500

Site (1200)

1.	Grading	\$ 240,000
2.	Drainage structures	11,700
3.	Paving	32,700
4.	Utilities (for building)	
	a. Electrical, underground	50,880
	b. Water	5,880
	c. Sewerage	90,000
	d. Communications	18,400
5.	Access roads	210,900
6.	Parking area	18,500
7.	Fencing	4,950
8.	Landscaping	5,000
		\$ 688,910

Administration (2100)

2 civilians @ 10K	\$ 20,000

Maintenance and Supply (2200)

1.	Janitorial service--\$0.50/ft^2/year for 35,750 ft^2	\$ 17,875
2.	Upkeep	10,000
3.	Repairs	10,000
4.	Maintenance supplies	10,000
5.	Utilities	
	a. Water, sewerage, gas	40,000
	b. Telephone	14,400
6.	Guards (5 @ 8K)	40,000
		\$ 142,275

COST DETAIL
ALTERNATIVE NO. 2B
COMPOUND BUILDING

Structure (1100)		
1.	Building, 30,750 ft^2 @ \$30/ft^2 (standard area)	\$ 922,500
	5000 ft^2 @ \$45/ft^2 (secure area)	225,000
2.	Special conductive treatment of roof	44,000
		\$1,191,500
Site (1200)		
1.	Grading	\$ 75,000
2.	Utilities (for building)	
	a. Electrical	
	Underground cable	42,400
	Overhead reinforcement	12,800
	Substation	70,600
	b. Water	4,900
	c. Sewerage	4,000
	d. Communications	10,600
3.	Parking area (no access road required)	18,500
4.	Fencing	4,950
		\$ 243,750
Administration (2100)		
	Administrative staff--2 civilians @ 10K	\$ 20,000
Maintenance and Support (2200)		
1.	Janitorial service--\$0.50/ft^2 year for 35,750 ft^2	\$ 17,875
2.	Upkeep	10,000
3.	Repairs	10,000
4.	Maintenance supplies	10,000
5.	Utilities	
	a. Water, sewerage, gas	40,000
	b. Telephone	14,400
6.	Guards (5 @ 8K)	40,000
		\$ 142,275

COST DETAIL
ALTERNATIVE NO. 3A
BATTERY ASHBURN

Structure (1100)

1.	Assume 7000 ft^2 now applicable and available	$ 0
2.	Convert 2000 ft^2 of undeveloped area	50,000
3.	Construct 26,750 ft^2 building on top	802,500
4.	Special conductive treatment of roof	44,000
		$ 896,500

Site (1200)

1.	Grading	$ 90,000
2.	Utilities--expand to new requirements	110,000
3.	Expand parking area	13,000
4.	Fencing	4,950
5.	Landscaping	5,000
6.	Access road	10,000
		$ 232,950

Administration (2100)

Administrative staff--2 civilians @ 10K	$ 20,000

Maintenance and Support (2200)

1.	Janitorial service--$0.50/$ft^2$/year for 35,750 ft^2	$ 17,875
2.	Upkeep	10,000
3.	Repairs	10,000
4.	Maintenance supplies	10,000
5.	Utilities	
	a. Water, sewerage, gas	40,000
	b. Telephone	14,400
6.	Guards (5 @ 8K)	40,000
		$ 142,275

COST DETAIL
ALTERNATIVE NO. 3B
LEASED BUILDING

<u>Structure</u> (1100)

1. Modify 5000 ft^2 @ \$15/ft^2 for security	\$	75,000
2. Designing and planning		75,000
3. Make compartments		200,000
First Cost (Fixed)	\$	350,000
Lease fee: 35,750 ft^2 @ \$2.40/ft^2/year	\$	85,800

<u>Site</u> (1200)

Landscaping	\$	5,000

<u>Administration</u> (2100)

Administrative staff--10 civilians @ 10K	\$	100,000

<u>Maintenance and Support</u> (2200)

1. Janitorial service--\$0.50/ft^2/year for 35,750 ft^2	\$	17,875
2. Upkeep		10,000
3. Repairs		10,000
4. Maintenance supplies		10,000
5. Utilities		
a. Water, sewerage, gas		40,000
b. Telephone		14,400
6. Guards (5 @ 8K)		40,000
	\$	142,275

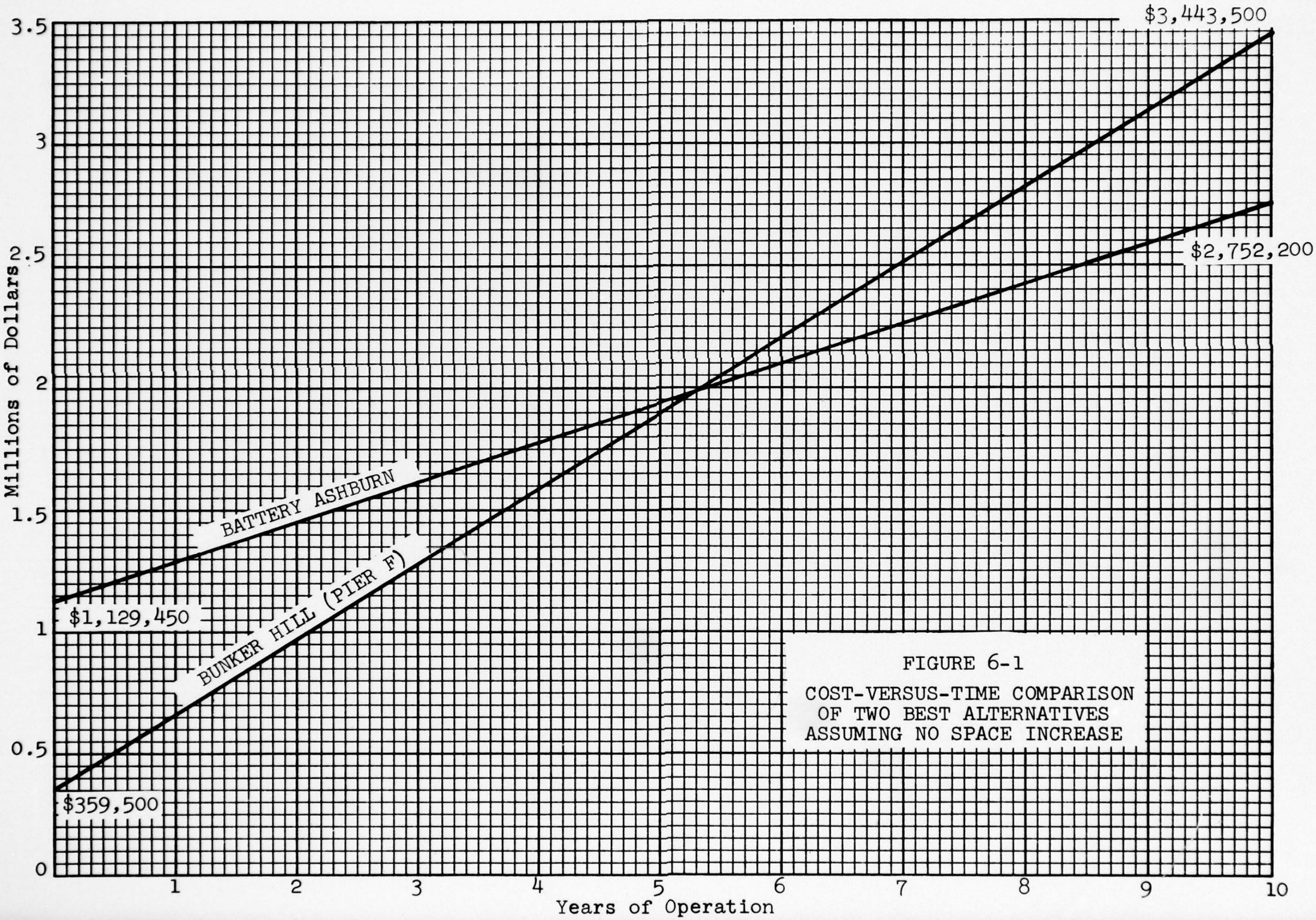

FIGURE 6-1

COST-VERSUS-TIME COMPARISON
OF TWO BEST ALTERNATIVES
ASSUMING NO SPACE INCREASE

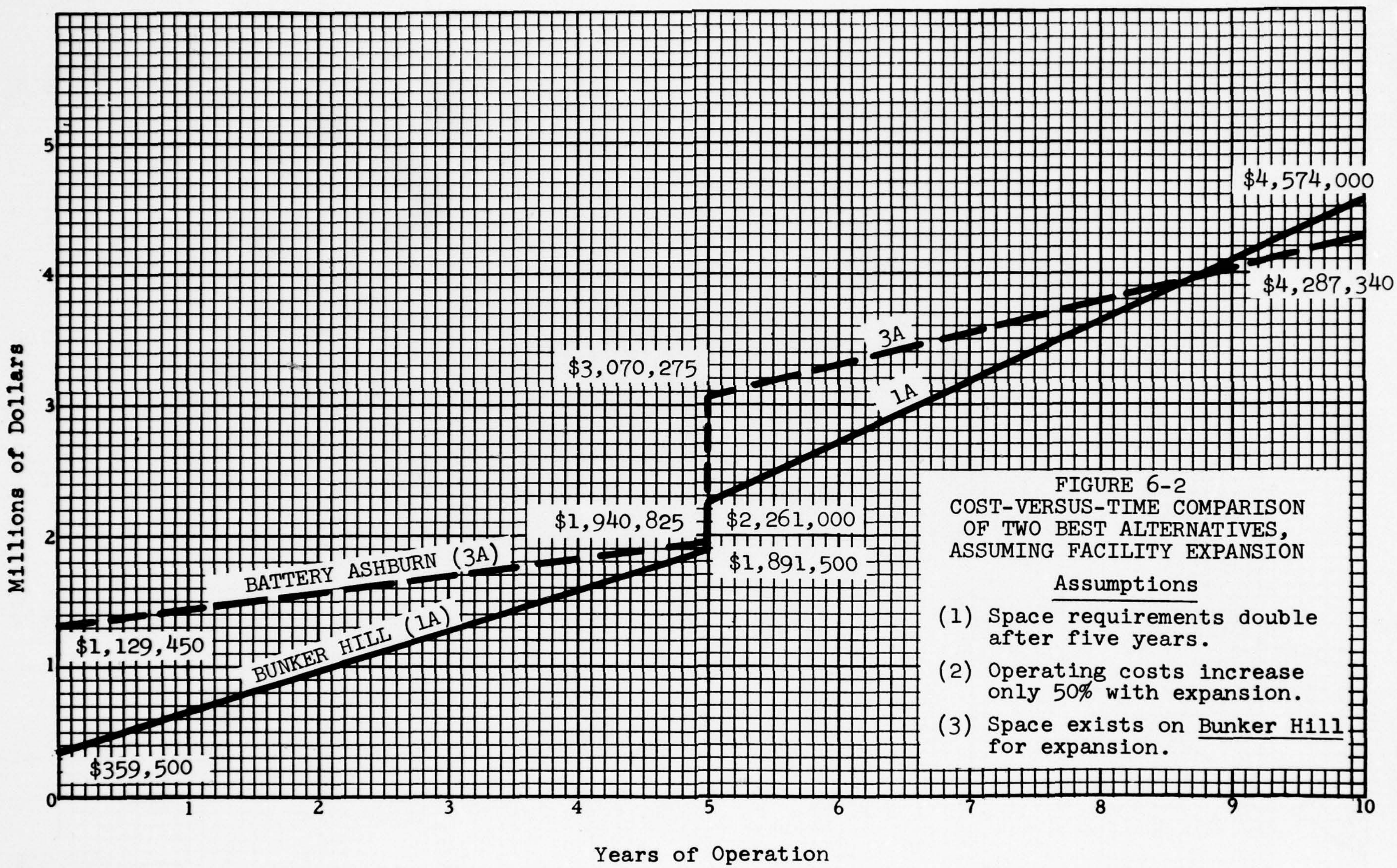

FIGURE 6-2
COST-VERSUS-TIME COMPARISON OF TWO BEST ALTERNATIVES, ASSUMING FACILITY EXPANSION

Assumptions

(1) Space requirements double after five years.

(2) Operating costs increase only 50% with expansion.

(3) Space exists on Bunker Hill for expansion.

7. FINANCIAL SUPPORT OF FACILITY

In an attempt to maintain an objective study approach, the cost and effectiveness analysis has been focused to a Navy-wide frame of reference. Nevertheless it is recognized that NEL management decisions must take account of the practical as well as the altruistic viewpoint--decisions in the "best interest of the Navy" do not necessarily assure financial support for the facility. The following discussion offers a rationale for evaluating this problem area and suggests an approach to solving the financial problem.

The system evaluation facility is, by nature, a multiple-user activity--in-house as well as non-NEL. Although initiated by the NSACS group, the facility will clearly have utility for other laboratory segments. Two specific out-of-house users are known: the Radioman Class A/B Schools and the Naval Security Group. The Personnel Research Laboratory, other Naval Material Command laboratories, and OPTEVFOR are other potential users of the facility.

In view of such widespread demand, it is not equitable that NEL bear the full burden of financial support of the facility and associated administrative costs. It is suggested that the facility could be operated by NEL as quasi-self-supporting. Users, whether in-house or non-NEL, would be required to directly fund any man-power and/or materials used directly in their utilization. In addition, users would be required to fund a share of the general administrative and overhead costs, and the facility maintenance and utilities cost, prorated on the basis of the proportion of the facility's capability employed. It is recognized that such an approach puts a burden on NEL to assure maximum utilization of the facility to avoid funding the overhead burden of the unused portion of the facility. However, from a management point of view, this could provide strong motivation for maintaining a high utilization rate.

This approach to financial support of the facility is a modified version of Navy Industrial Fund (NIF) operation. The NEL accounting is currently on a modified NIF basis. As a result, this approach would not introduce undue difficulty in accounting, other than to require the setting up of a separate account for the facility. Table 7-1 shows comparative ten-year costs for 25 percent, 50 percent, 75 percent, and 90 percent utilization of the facility alternates under this suggested approach to financial support.

Successful application of this approach would be contingent upon establishing the percent of total capability represented by the various segments of the facility as a basis for determining the charges to be assigned to the users. However, once a

schedule is established, it need not be modified unless significant facilities changes are made. Study might indicate the feasibility of a schedule as simple as one based on square-footage.

TABLE 7-1

COMPARATIVE FACILITY COSTS
FOR DIFFERENT PERCENTAGES OF UTILIZATION

Alternative (§2.2.2)	Acquisition Cost	NEL Maintenance and Support Costs (10 years)			
		25 Percent Utility	50 Percent Utility	75 Percent Utility	90 Percent Utility
	$	$	$	$	$
1A	359,500	2,313,000	1,542,000	771,000	308,400
1B	1,538,800	1,563,000	1,042,000	521,000	208,400
2A	1,880,400	1,217,068	811,375	405,682	162,275
2B	1,435,250	1,217,068	811,375	405,682	162,275
3A	1,129,450	1,217,068	811,375	405,682	162,275
3B	355,000	2,460,563	1,640,375	820,187	328,075